# Introduction to Simulation Analysis of Space Shuttle Manifest Options

# ***Input Analysis***

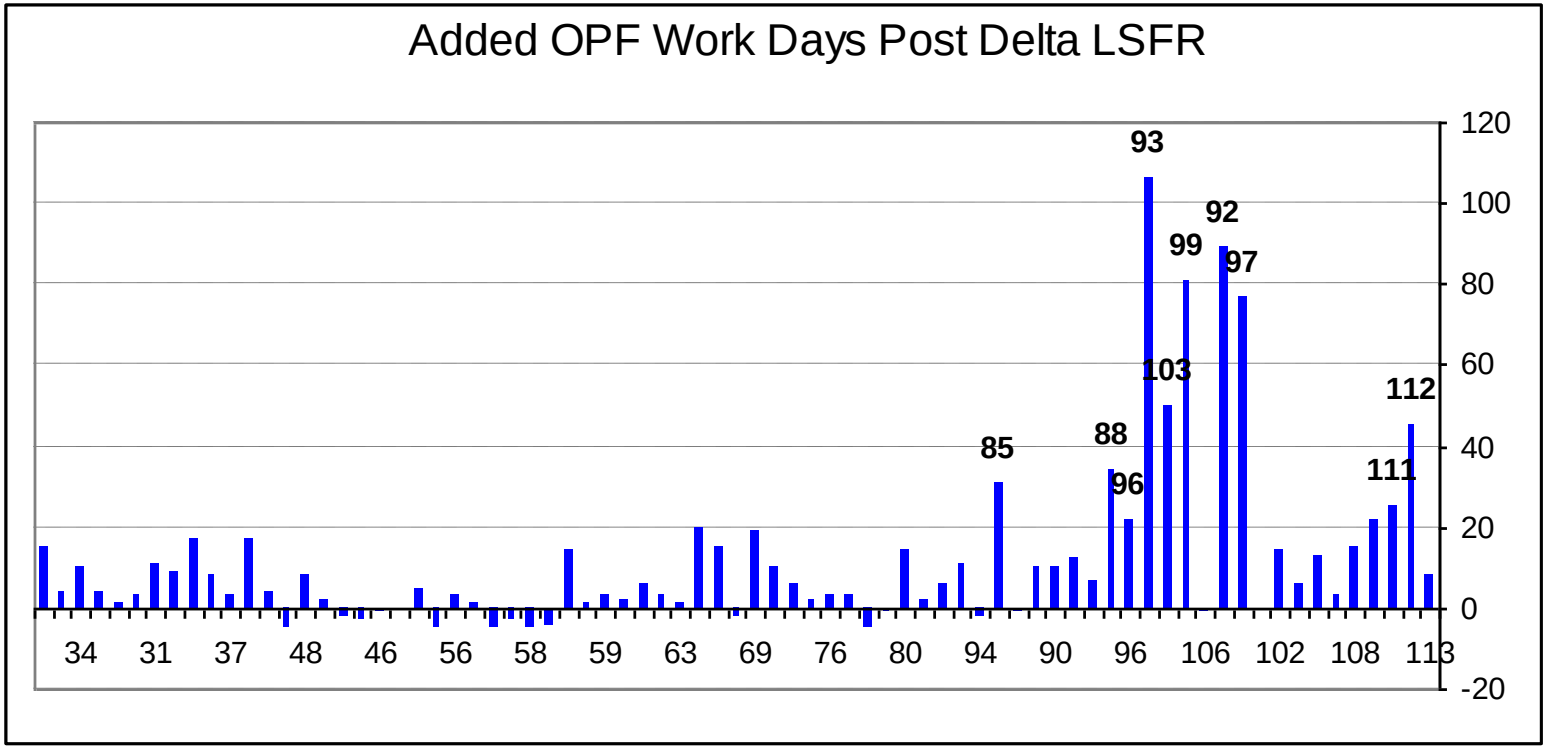
***Now includes unique OMDP analysis***

April 9, 2004

Grant Cates

PH-M3

# OPF Run Chart for Added Work Days

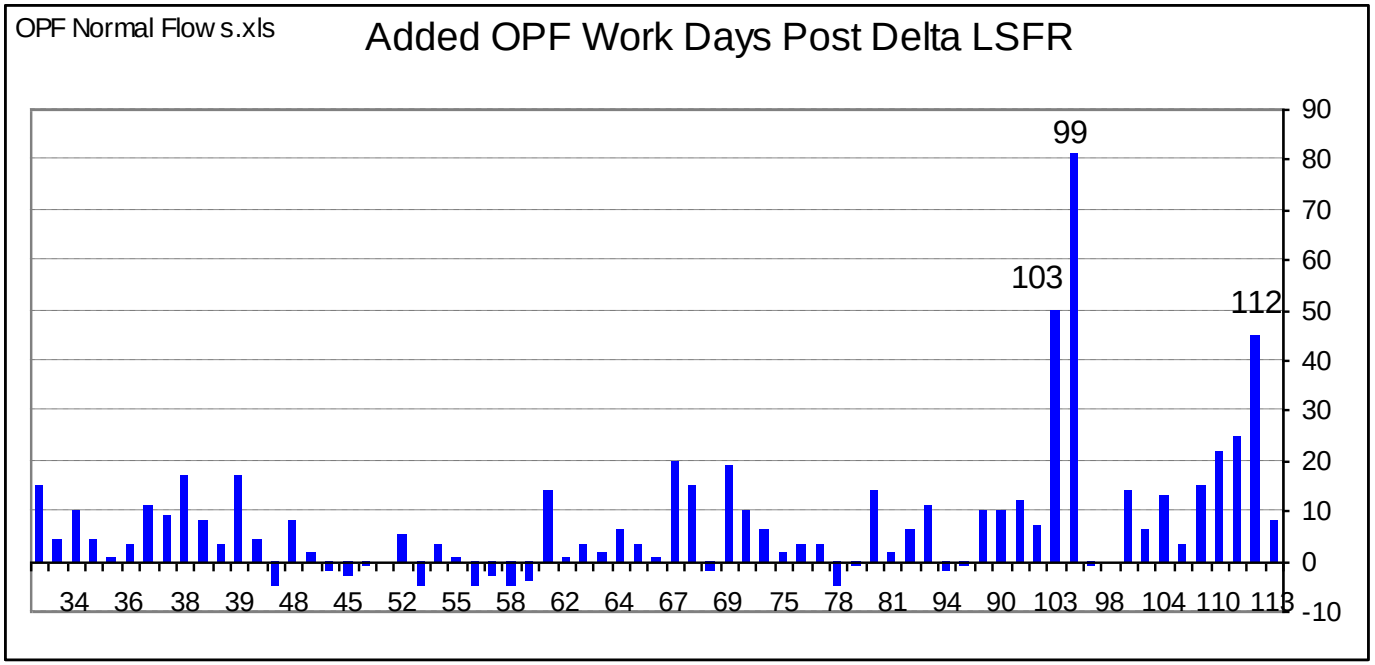



Sources of added work days include new program requirements (chits and modifications) and PRACA.

STS-85 (Impacted by reflight of STS-83)
STS-88 (ISS late hardware)
STS-96 (Delay to STS-93 created additional time in OPF, low flight rate)
STS-93 (AXAF Payload Delays created opportunity to add work)
STS-103 (Wiring Inspections)
STS-99 (Wiring Inspections)
STS-92 (Launch Date Rebaselining created opportunity to add work)
STS-97 (Same as 92)
STS-111 (SSRMS Integration)
STS-112 (MPS Flow Liner)

# OPF Run Chart for Added Work Days

## (After Removal of Selected Low Flight Rate Related Flows)

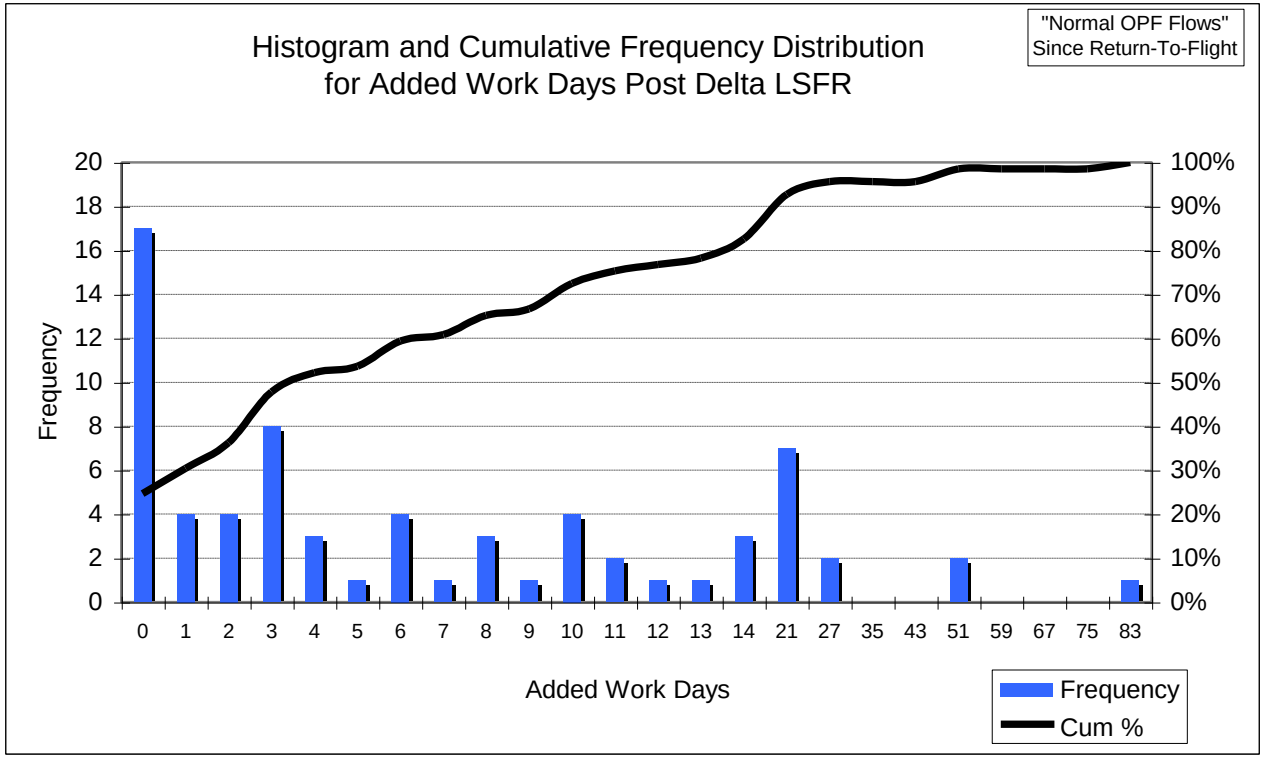



STS-85 (Impacted by reflight of STS-83) was removed.
STS-88 (ISS late hardware) was removed.
STS-96 (Delay to STS-93 created additional time in OPF, low flight rate) was removed.
STS-93 (AXAF Payload Delays created opportunity to add work) was removed.
STS-103 (Wiring Inspections)
STS-99 (Wiring Inspections)
STS-92 (Launch Date Rebaselining created opportunity to add work) was removed.
STS-97 (Same as 92) was removed.
STS-111 (SSRMS Integration)
STS-112 (MPS Flow Liner)

# OPF Histogram and Cumulative Frequency Distribution for Added Work Days Post Delta LSFR

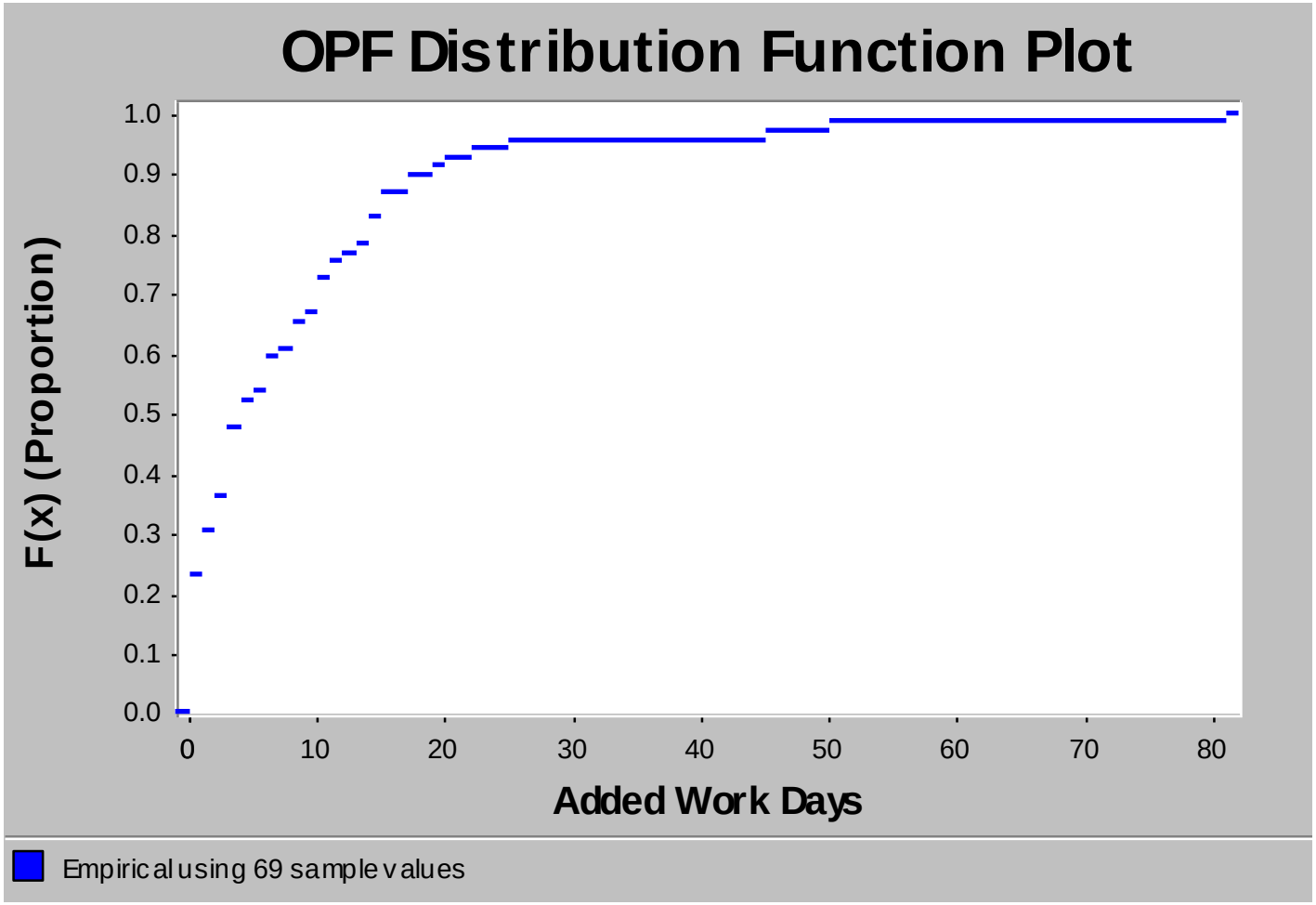
## Data from Selected Low Flight Rate Related Flows Removed

| Added Days | Freq | Cum % |
|---|---|---|
| 0 | 17 | 25% |
| 1 | 4 | 30% |
| 2 | 4 | 36% |
| 3 | 8 | 48% |
| 4 | 3 | 52% |
| 5 | 1 | 54% |
| 6 | 4 | 59% |
| 7 | 1 | 61% |
| 8 | 3 | 65% |
| 9 | 1 | 67% |
| 10 | 4 | 72% |
| 11 | 2 | 75% |
| 12 | 1 | 77% |
| 13 | 1 | 78% |
| 14 | 3 | 83% |
| 21 | 7 | 93% |
| 27 | 2 | 96% |
| 35 | 0 | 96% |
| 43 | 0 | 96% |
| 51 | 2 | 99% |
| 59 | 0 | 99% |
| 67 | 0 | 99% |
| 75 | 0 | 99% |
| 83 | 1 | 100% |



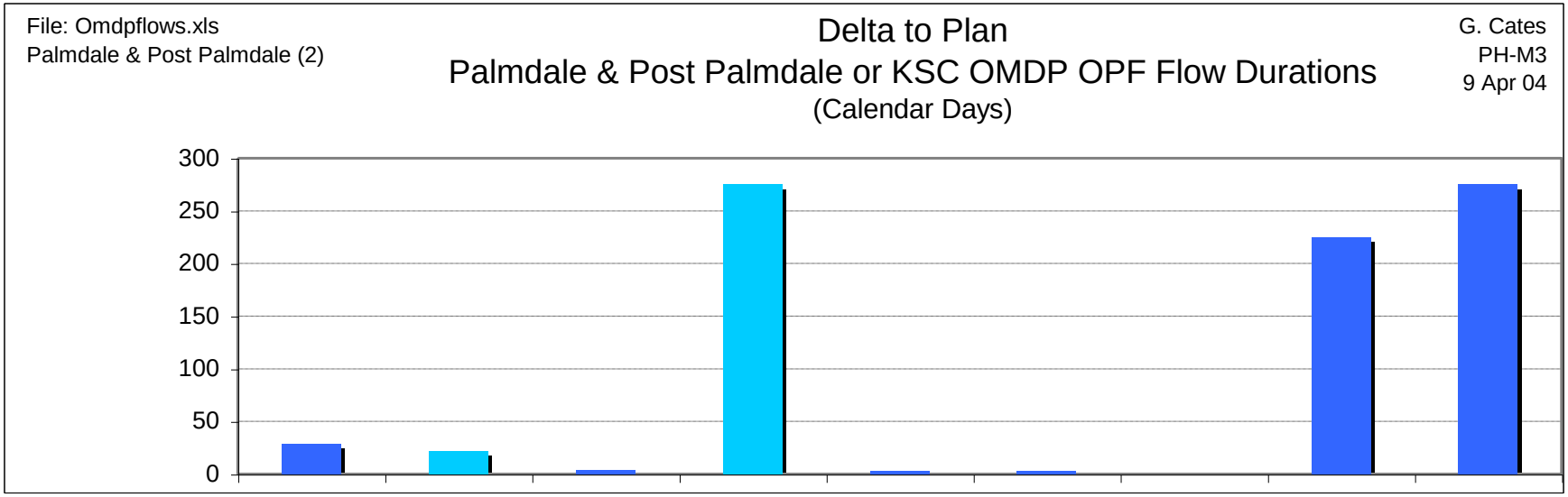

Having the ability to absorb 4 added work days will preserve the the ability to rollout of the OPF on time with a **.5** probability.
To increase that probability to **.9** would require the ability to absorb approximately 21 added work days.

# Modeling OPF Added Work




Arena Representation: DISC(0.2319,0, 0.3043,1, 0.3623,2, 0.4783,3, 0.5217,4, 0.5362,5, 0.5942,6, 0.6087,7, 0.6522,8, 0.6667,9, 0.7246,10, 0.7536,11, 0.7681,12, 0.7826,13, 0.8261,14, 0.8696,15, 0.8986,17, 0.9130,19, 0.9275,20, 0.9420,22, 0.9565,25, 0.9710,45, 0.9855,50, 1.0,81)

# OMDP Flow Run Chart for Added Days

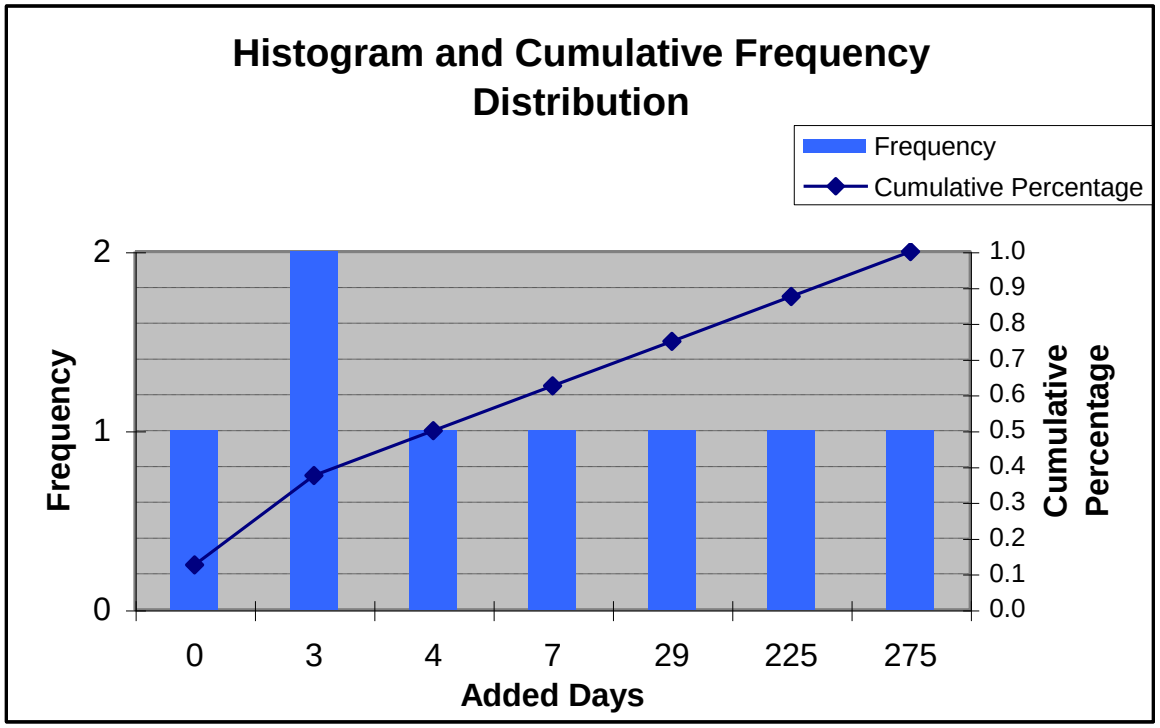



| | STS-50 | STS-49 | STS-53 | STS-66 | STS-73 | STS-82 | STS-89 | STS-101 | STS-109 |
|---|---|---|---|---|---|---|---|---|---|
| Orbiter | OV-10**2** | OV-105 | OV-103 | OV-10**4** | OV-10**2** | OV-10**3** | OV-10**5** | OV-10**4** | OV-10**2** |
| Purpose | EDO Mod I-5 Flow | Initial Build | OMDP-1 at **KSC** | OMDP-1 | OMDP-1 | OMDP-2 | OMDP-1 | OMDP-2 | OMDP-2 |
| Palmdale Delta | 9 | | | 268 | -1 | -1 | -13 | 32 | 238 |
| Post Palmdale Delta | 20 | 22 | | 7 | 4 | 4 | 11 | 193 | 37 |
| KSC Delta | | | 4 | | | | | | |
| Total Delta | 29 | 22 | 4 | 275 | 3 | 3 | -2 | 225 | 275 |
| | | | | Remanifest | | | | Wire Inspections | |
| Data used for Simulation | 29 | | 4 | | 3 | 3 | 0 | 225 | 275 |

# OMDP Type Flows

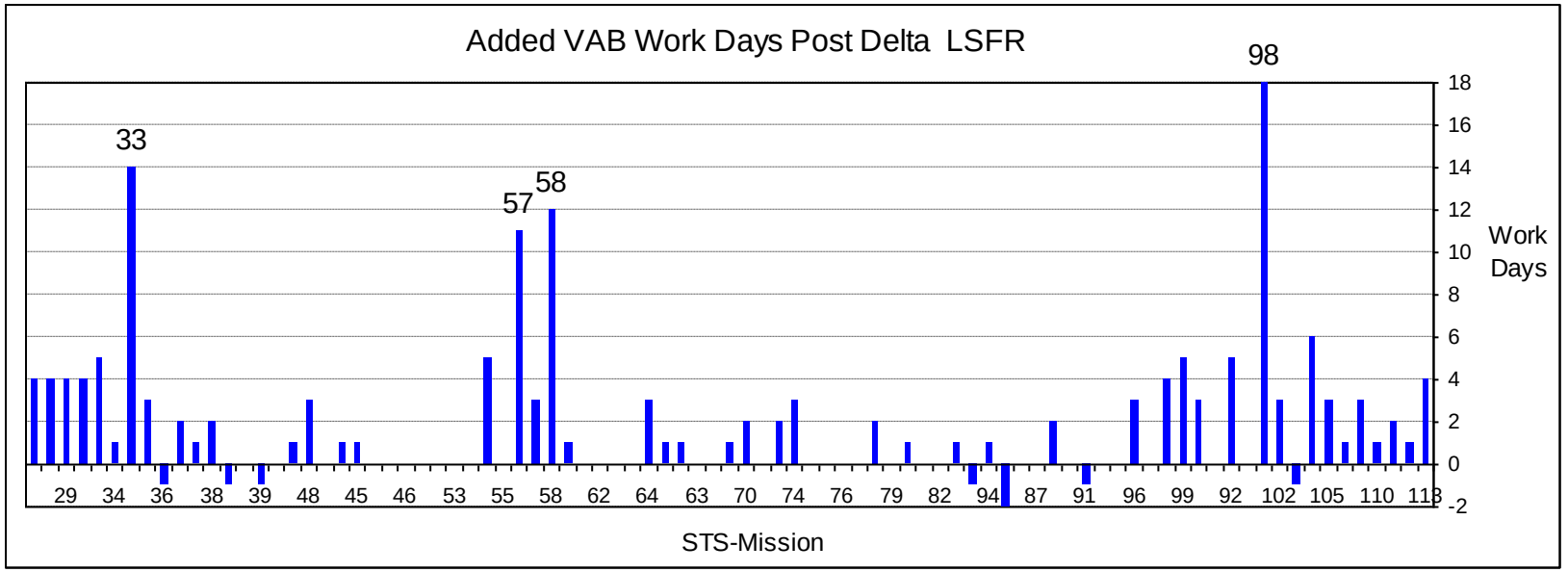
## Histogram and Cumulative Frequency Distribution for Added Days
## Arena Representation

| Added Days | Frequency | Cumulative Percentage |
|---|---|---|
| 0 | 1 | 0.125 |
| 3 | 2 | 0.375 |
| 4 | 1 | 0.500 |
| 7 | 1 | 0.625 |
| 29 | 1 | 0.750 |
| 225 | 1 | 0.875 |
| 275 | 1 | 1.000 |
| | 8 | |




Arena Representation:
DISC(0.125,0, 0.375,3, 0.500,4, 0.625,7, 0.750,29, 0.875,225, 1.000,275)

# VAB

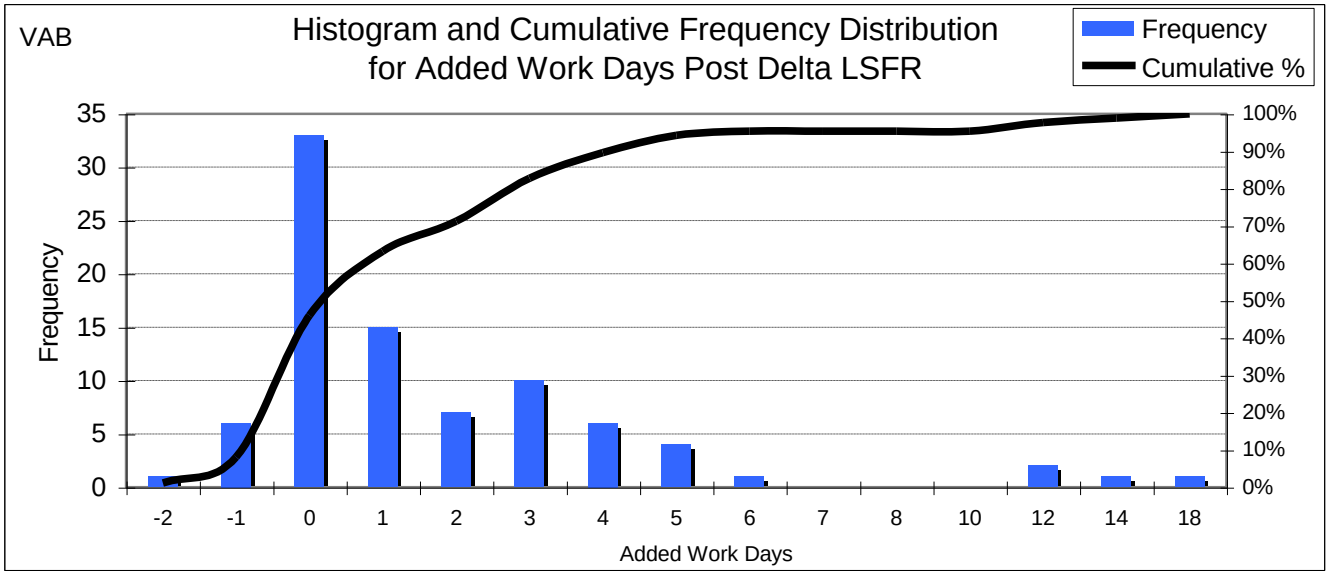



Sources of added work days are typically PRACA related.

STS-33 (SSME HPOTP installation in VAB)
STS-57 (Engine Installation in VAB)
STS-58 (Pad Unavailability)
STS-98 (ET/SRB Pyro Cable Inspections)

# VAB

| Added Days | Frequency | Cumulative % |
|---|---|---|
| -2 | 1 | 1% |
| -1 | 6 | 8% |
| 0 | 33 | 46% |
| 1 | 15 | 63% |
| 2 | 7 | 71% |
| 3 | 10 | 83% |
| 4 | 6 | 90% |
| 5 | 4 | 94% |
| 6 | 1 | 95% |
| 7 | 0 | 95% |
| 8 | 0 | 95% |
| 10 | 0 | 95% |
| 12 | 2 | 98% |
| 14 | 1 | 99% |
| 18 | 1 | 100% |
| | 87 | |

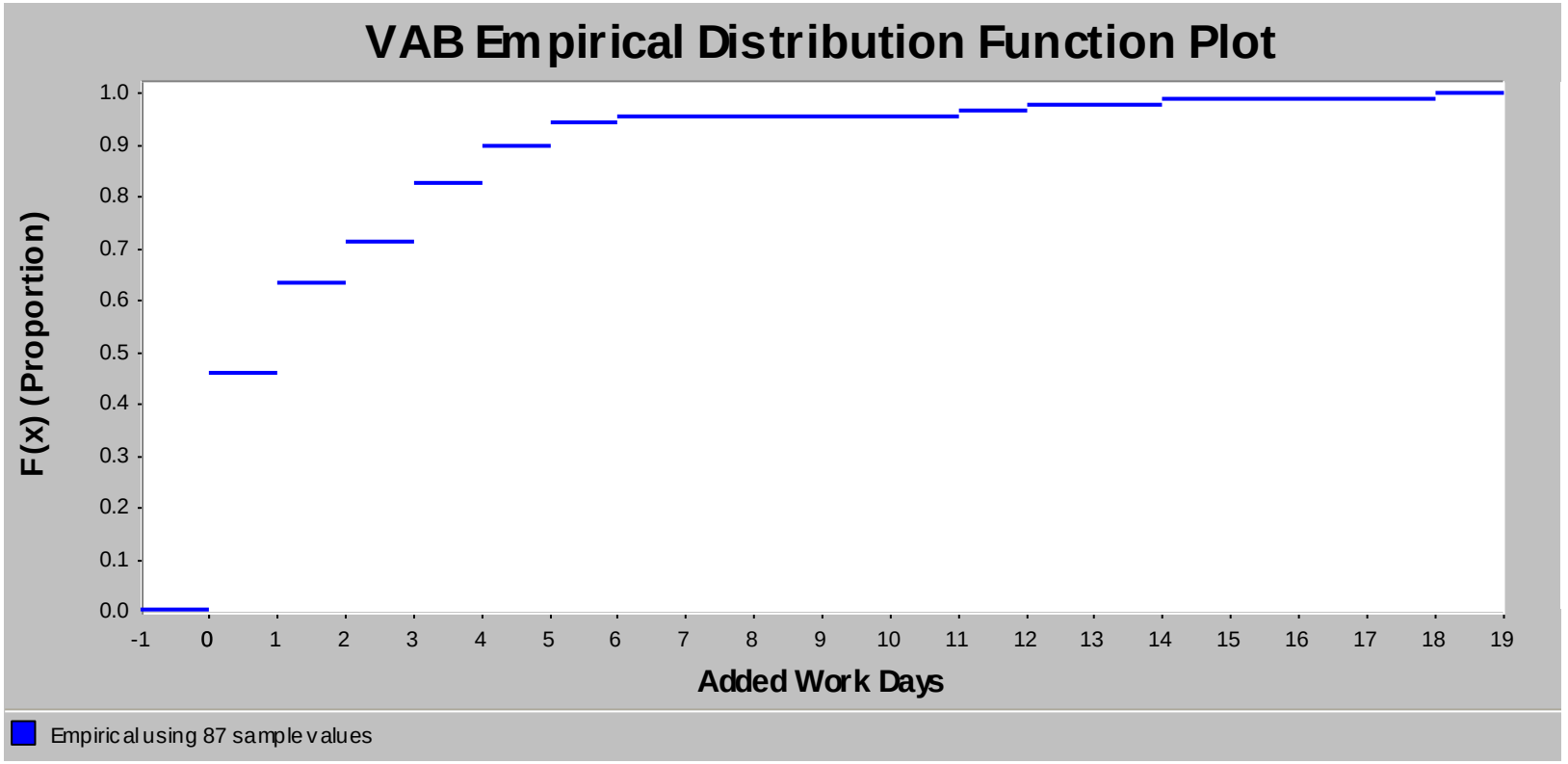



Approximately 50 percent of the time, no work days are added to the VAB flow.

Having the ability to absorb **2** added work days will preserve the the ability to rollout of the VAB on time with a **.7** probability.

To increase that probability to **.9** would require the ability to absorb approximately **4** added work days.

# Modeling VAB Added Work

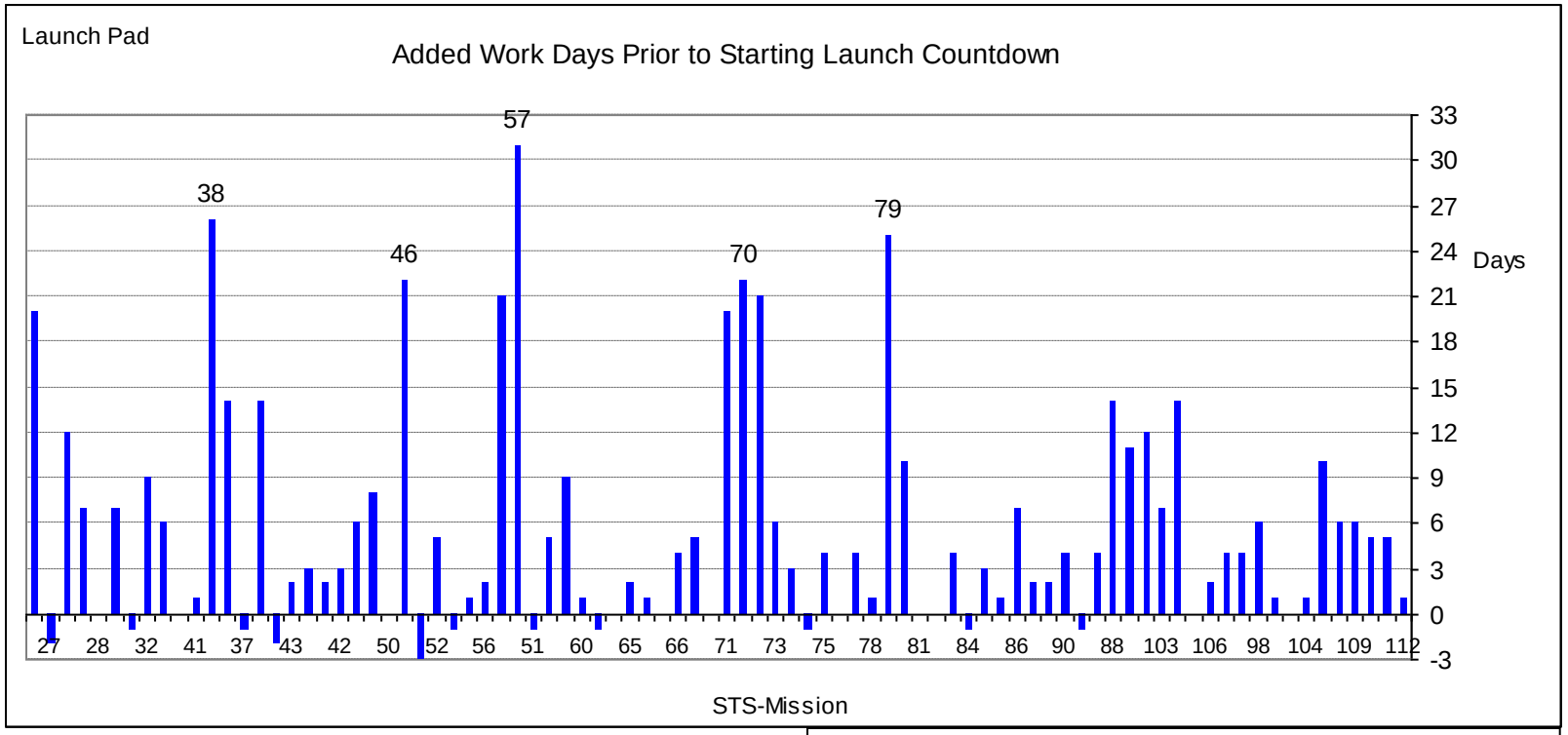



Arena Representation:

DISC(0.4598,0, 0.6322,1, 0.7126,2, 0.8276,3, 0.8966,4, 0.9425,5,
0.9540,6, 0.9655,11, 0.9770,12, 0.9885,14, 1.0000,18)

# Launch Pad

(Prior to Beginning Countdown)



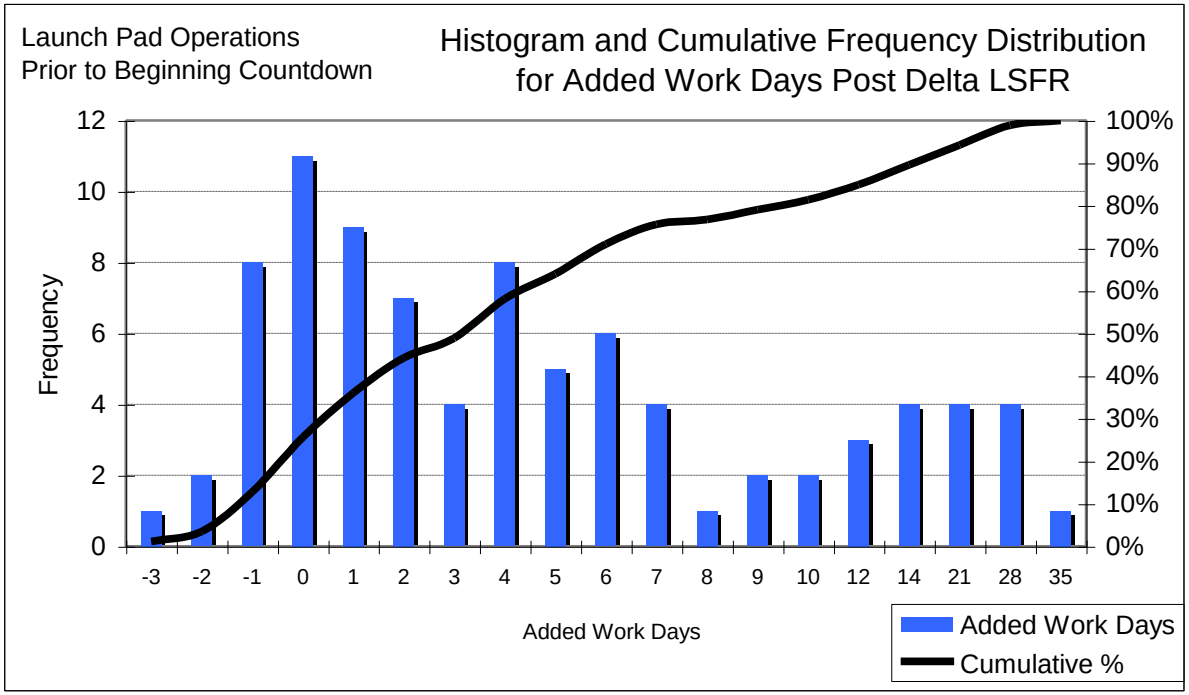

Sources of added work days are typically PRACA or Environment related.

STS-38 (Added Mini-Tanking Test, & P/L Problem)
STS-46 (Flight Crew and MOD Training)
STS-57 (Replace HPOTP, & Investigate "Big Bang")
STS-70 (Woodpeckers)
STS-79 (Two Hurricane Rollbacks & Booster Replacement)

# Launch Pad

## Prior to Beginning Launch Countdown

| Added Work Days | Frequency | Cumulative % |
|---|---|---|
| -3 | 1 | 1% |
| -2 | 2 | 3% |
| -1 | 8 | 13% |
| 0 | 11 | 26% |
| 1 | 9 | 36% |
| 2 | 7 | 44% |
| 3 | 4 | 49% |
| 4 | 8 | 58% |
| 5 | 5 | 64% |
| 6 | 6 | 71% |
| 7 | 4 | 76% |
| 8 | 1 | 77% |
| 9 | 2 | 79% |
| 10 | 2 | 81% |
| 12 | 3 | 85% |
| 14 | 4 | 90% |
| 21 | 4 | 94% |
| 28 | 4 | 99% |
| 35 | 1 | 100% |
| | 86 | |

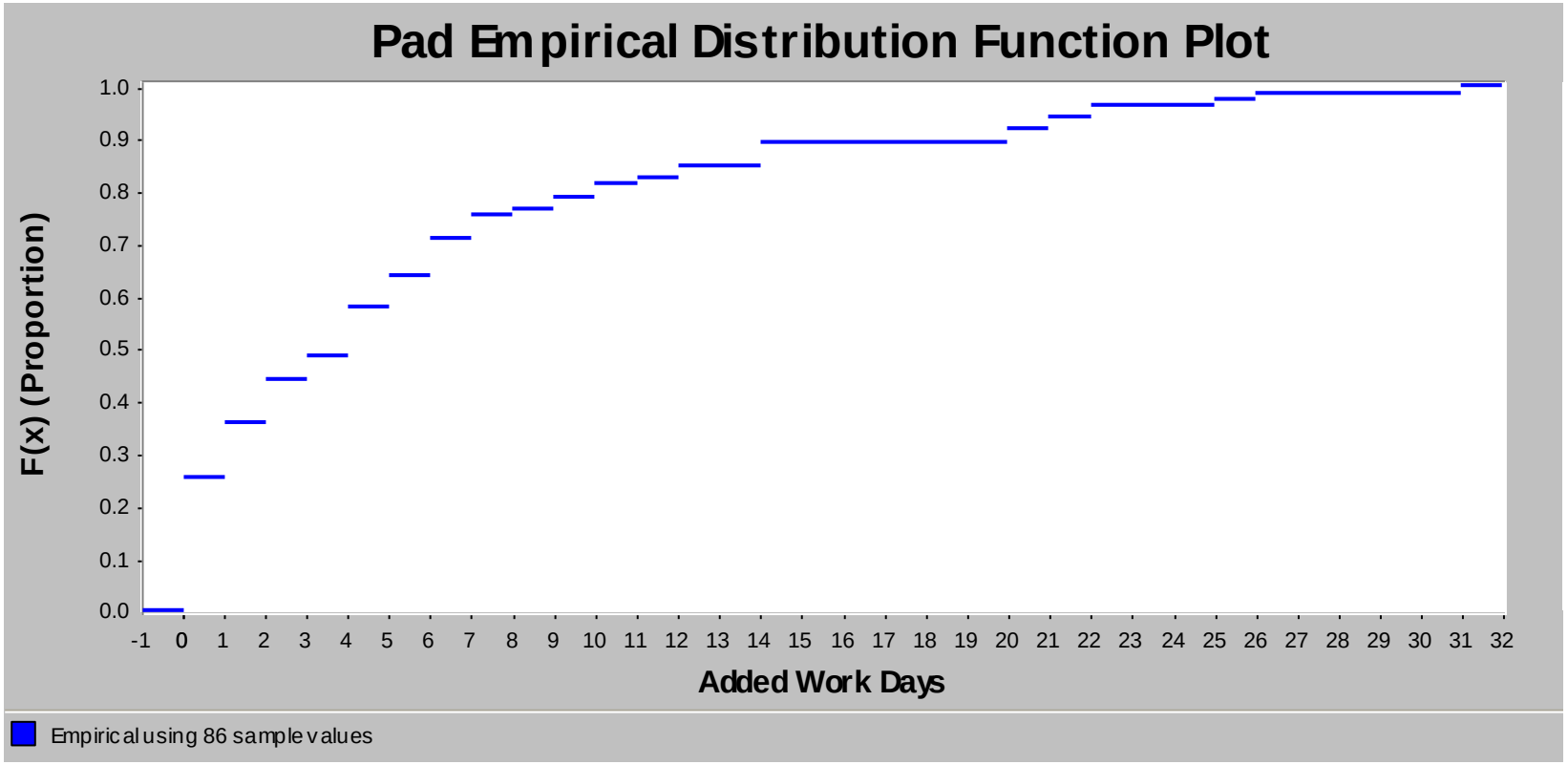



Approximately 25 percent of the time, no work days are added to the Pad flow (not including launch countdown).

Having the ability to absorb **3** added work days will preserve the ability to begin countdown on time with a **.5** probability.

To increase that probability to **.9** would require the ability to absorb approximately **14** added work days.

# Modeling Launch Pad Added Work



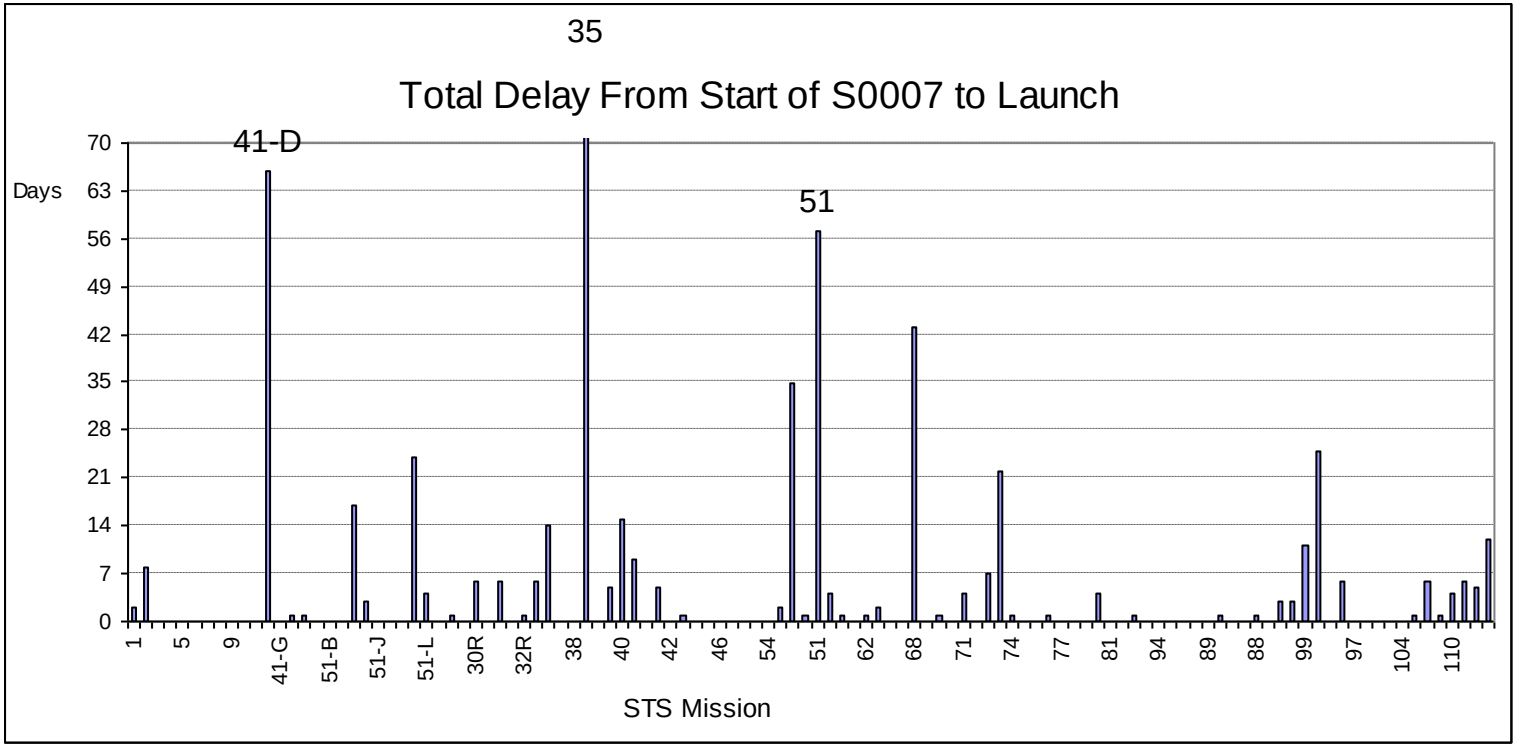

Arena Representation:

DISC(0.2558,0, 0.3605,1, 0.4419,2, 0.4884,3, 0.5814,4, 0.6395,5, 0.7093,6, 0.7558,7, 0.7674,8, 0.7907,9, 0.8140,10, 0.8256,11, 0.8488,12, 0.8953,14, 0.9186,20, 0.9419,21, 0.9651,22, 0.9767,25, 0.9884,26, 1.0000,31)

# Launch Countdown Delays
# General Information

- How often is a planned launch attempt delayed one or more days once the countdown has started?
  - Approximately 45 percent.
- What are the general categories of the causes for the delay?
  - Flight Hardware
  - Weather
  - Infrastructure
  - Operational Prerogative
- When do delays occur?
  - Prior to Tanking (L-2 Day, L-1 Day, or at Pre-Tanking MMT)
  - During Tanking
  - After Tanking
    - T-3 Hour Hold, Counting to T-20 minutes, At T-20 Minute Hold, At T-9 Minute Hold, During Terminal Count

# Post-S0007-Start Delay History



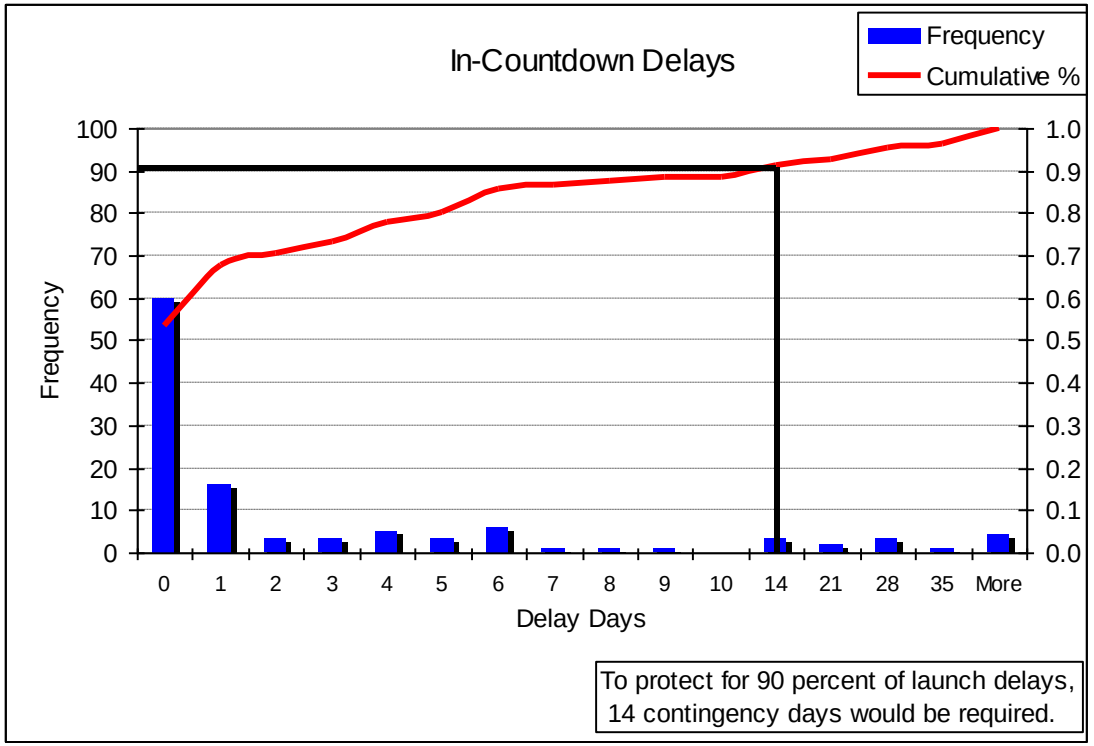

STS-41-D (SSME Abort, VAB return for SSME replacement)
STS-35 (Total of 166 days for Hydrogen Leaks)
STS-51 (Three scrubs/delays… MLP Ordnance, SRB HPU, & SSME abort)

# Post S0007-Start Delay Durations

(Cumulative Frequency Distribution)
Based on historical data since STS-1.

Since STS-1

| Delay (Days) | Frequency | Cumulative % |
|---|---|---|
| 0 | 60 | 53.6% |
| 1 | 16 | 67.9% |
| 2 | 3 | 70.5% |
| 3 | 3 | 73.2% |
| 4 | 5 | 77.7% |
| 5 | 3 | 80.4% |
| 6 | 6 | 85.7% |
| 7 | 1 | 86.6% |
| 8 | 1 | 87.5% |
| 9 | 1 | 88.4% |
| 10 | 0 | 88.4% |
| 14 | 3 | 91.1% |
| 21 | 2 | 92.9% |
| 28 | 3 | 95.5% |
| 35 | 1 | 96.4% |
| More | 4 | 100.0% |
| | 112 | |



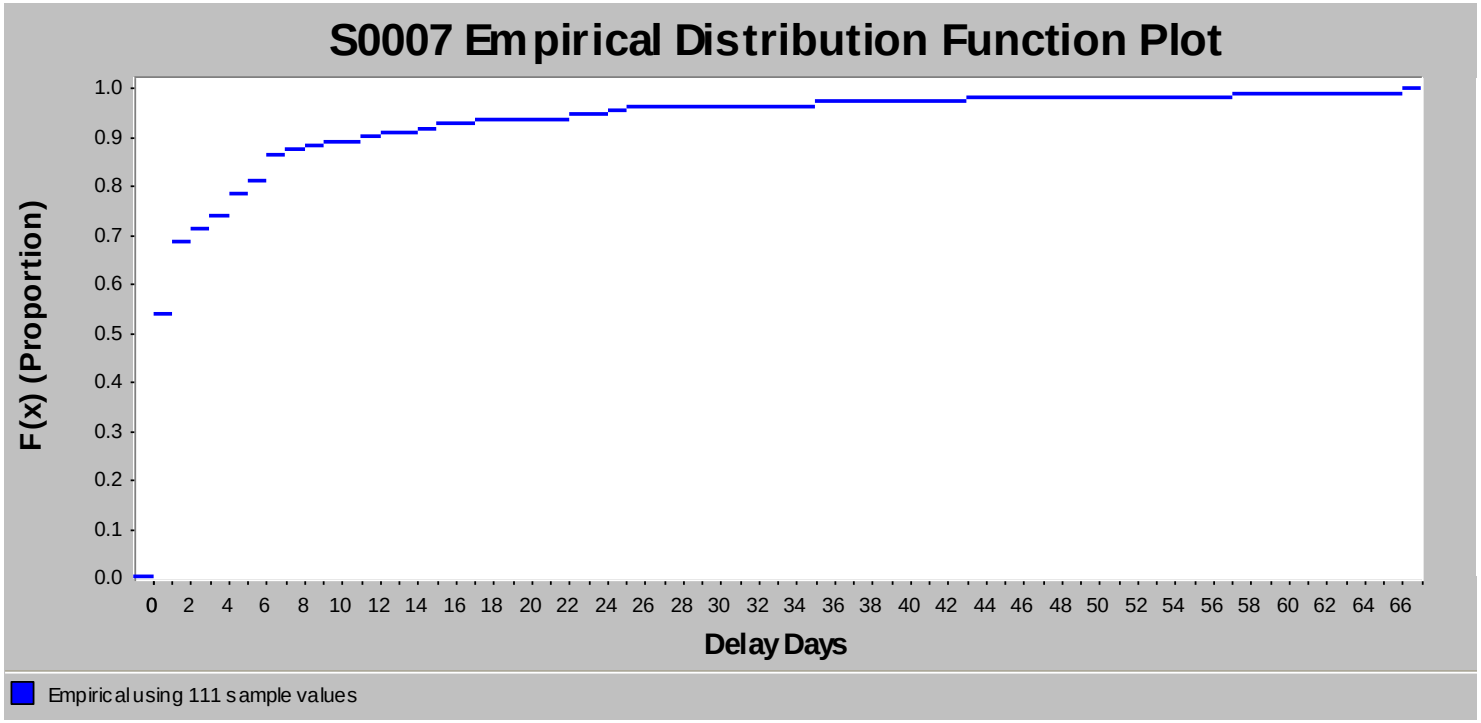

Approximately 54% percent of the time, launch occurs on time once the count has started.

Having the ability to absorb **2** delay days in the down stream OPF flow will preserve the the ability to achieve an on time OPF rollout with **.7** probability.

To increase that probability to **.9** would require the ability to absorb approximately **14** delay days.

# Modeling Post S0007-Start Delay Days

(Excludes STS-35)

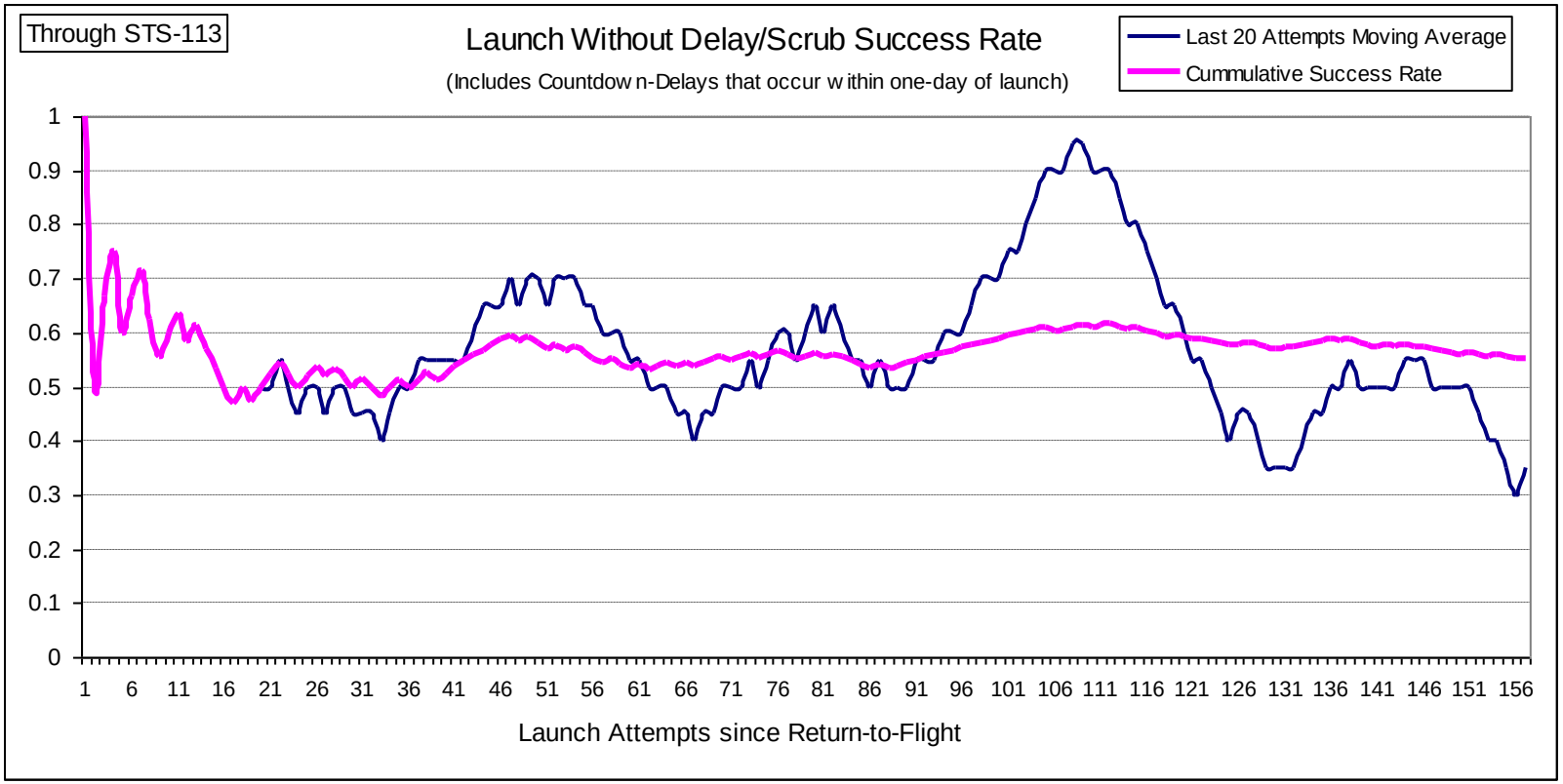



Arena Representation:

DISC(0.5405,0, 0.6847,1, 0.7117,2, 0.7387,3, 0.7838,4, 0.8108,5, 0.8649,6, 0.8739,7, 0.8829,8, 0.8919,9, 0.9009,11, 0.9099,12, 0.9189,14, 0.9279,15, 0.9369,17, 0.9459,22, 0.9550,24, 0.9640,25, 0.9730,35, 0.9820,43, 0.9910,57, 1.0000,66)

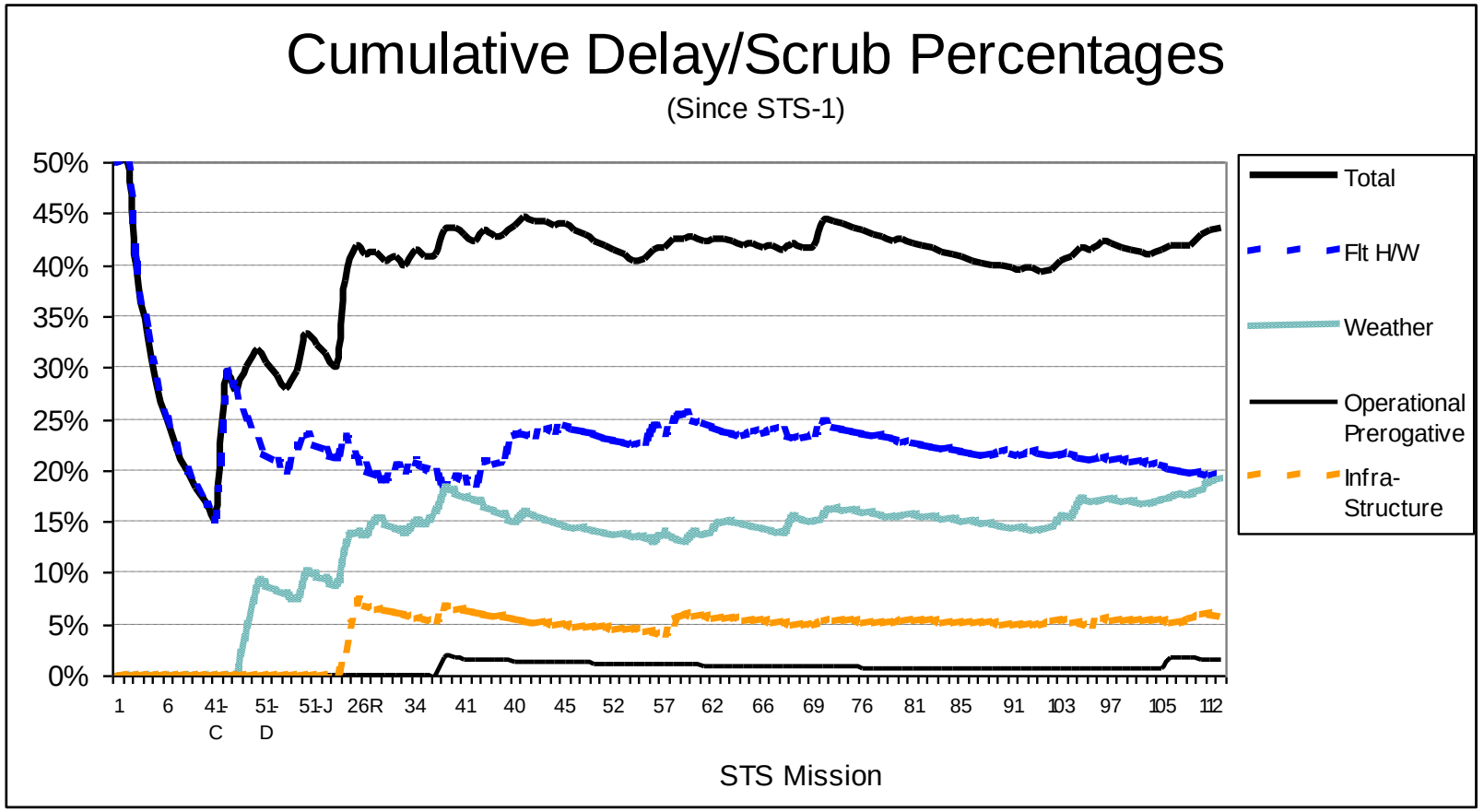
# Launch Success Rate Moving Average

(20-launch-attempt moving average)
Since Return-to-Flight



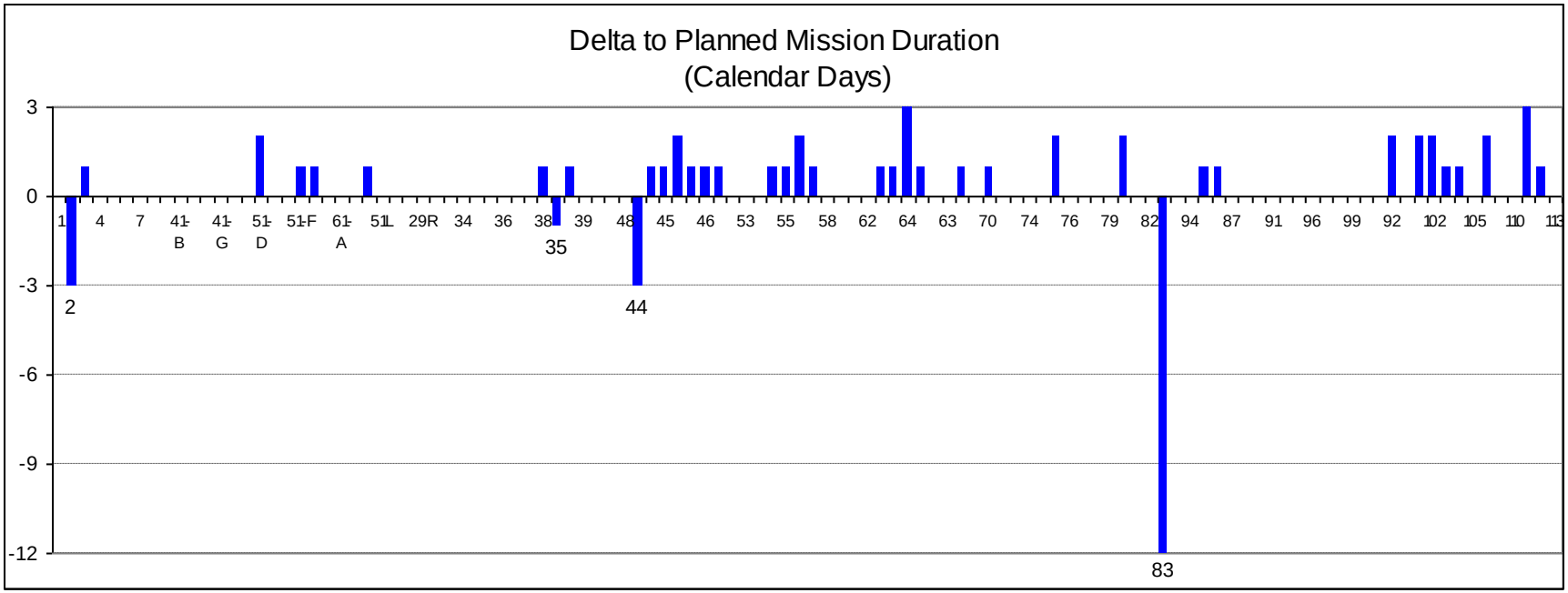
# Cumulative Delay/Scrub Percentages

(Since STS-1)




- Reliability of Flight Hardware Improving
- Delays/Scrubs attributable to Weather Increasing

# Mission Duration




Sources of **added** on-orbit mission days include added planned days from the program post Delta LSFR, on-orbit problems, and delays for landing weather.

Reasons for **shortened** missions are typically flight hardware problems.

STS-2 (Number 1 Fuel Cell Failure)

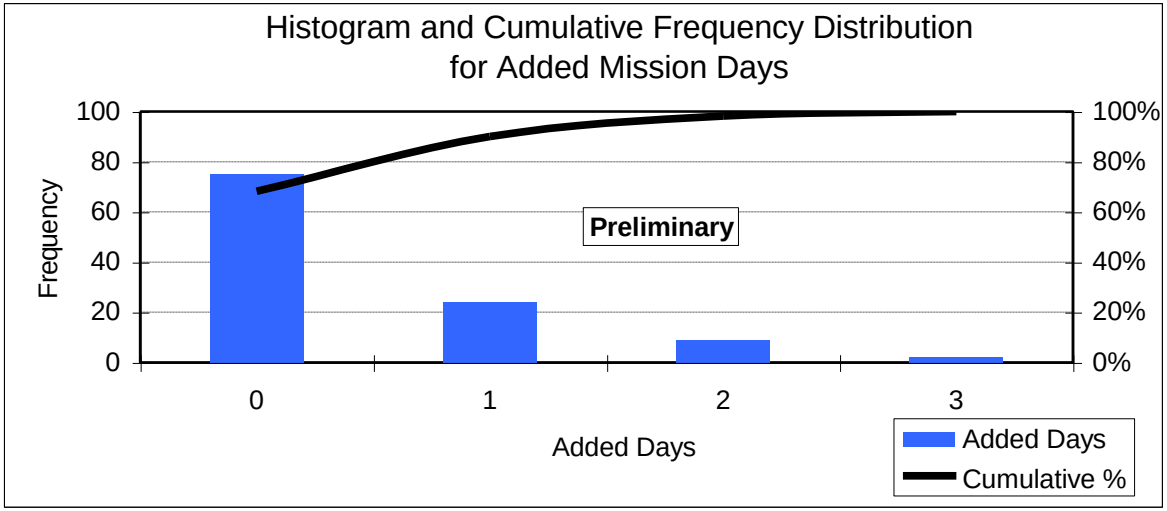
STS-35 (Orbiter landed one day early in advance of bad weather)

STS-44 (Failure of one of three IMUs)

STS-83 (Fuel Cell #2 Suspect Problem)

# Mission Duration

| Added Days | Frequency | Cumulative % |
|---|---|---|
| 0 | 75 | 68% |
| 1 | 24 | 90% |
| 2 | 9 | 98% |
| 3 | 2 | 100% |
| | 110 | |



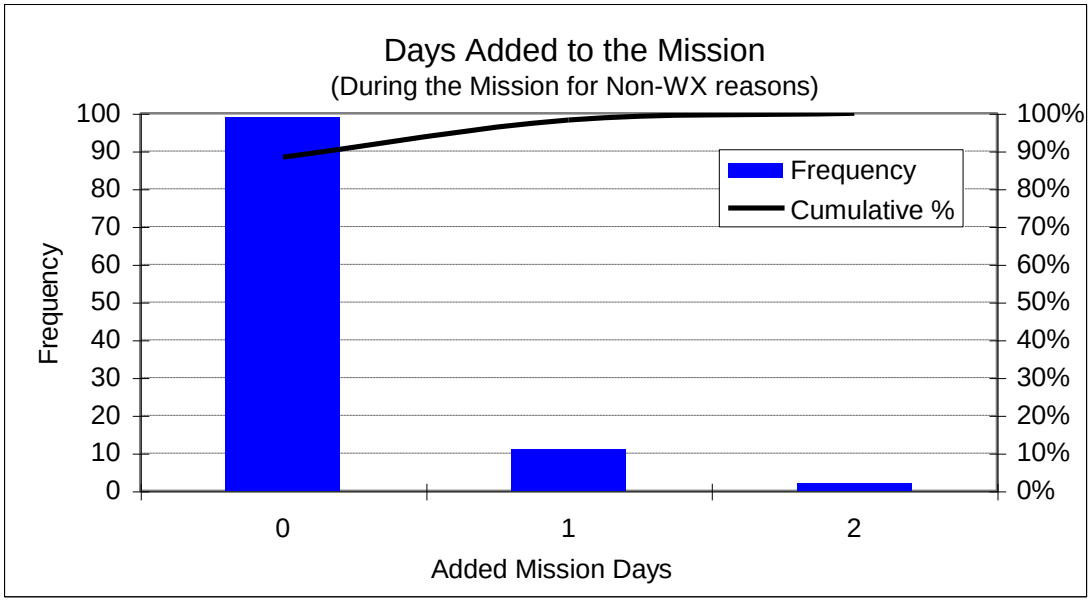

Approximately 70 percent of the time, the planned mission duration is not increased.

Having the ability to absorb the effect 1 added mission day in the down stream OPF flow with be adequate 90 percent of the time.

There is a correlation between missions that have added days and missions that land at DFRC. The last 10 missions diverted to DFRC have averaged one additional day on orbit for weather.

# Non-WX Mission Day Additions

| Days | Frequency | Cum. % |
|---|---|---|
| 0 | 99 | 88% |
| 1 | 11 | 98% |
| 2 | 2 | 100% |

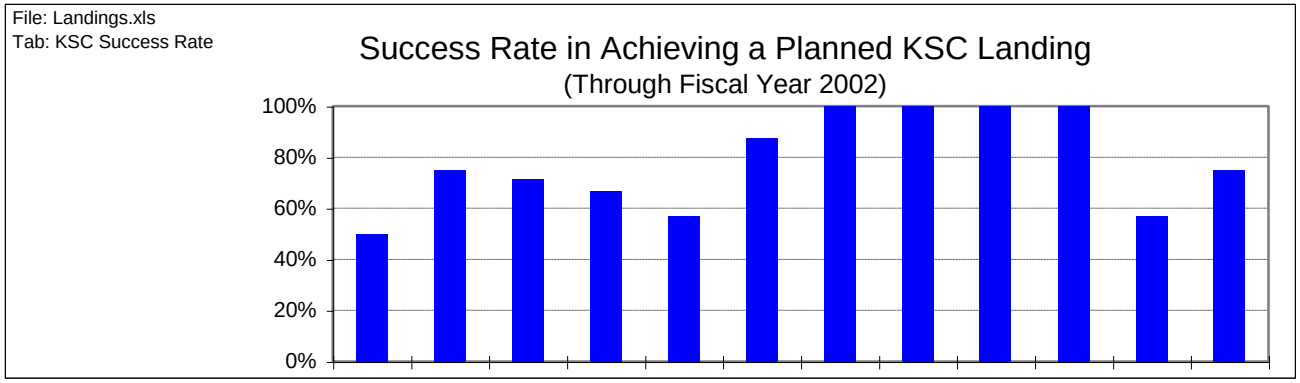



Arena model representation

DISC (.88, 0, .98, 1, 1.0, 2)

# KSC Landing Success

File: Landings.xls
Tab: KSC Success Rate




| Fiscal Year | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | Totals |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Planned KSC Landings | 2 | 4 | 7 | 6 | 7 | 8 | 7 | 5 | 4 | 4 | 7 | 4 | 1 | 66 |
| Achieved KSC Landings | 1 | 3 | 5 | 4 | 4 | 7 | 7 | 5 | 4 | 4 | 4 | 3 | 1 | 52 |
| Missions Diverted to DFRC | 1 | 1 | 2 | 2 | 3 | 1 | 0 | 0 | 0 | 0 | 3 | 1 | 0 | 14 |
| Success Rate | 50% | 75% | 71% | 67% | 57% | 88% | 100% | 100% | 100% | 100% | 57% | 75% | 100% | 79% |

# Mission Extension Days for Landing Weather

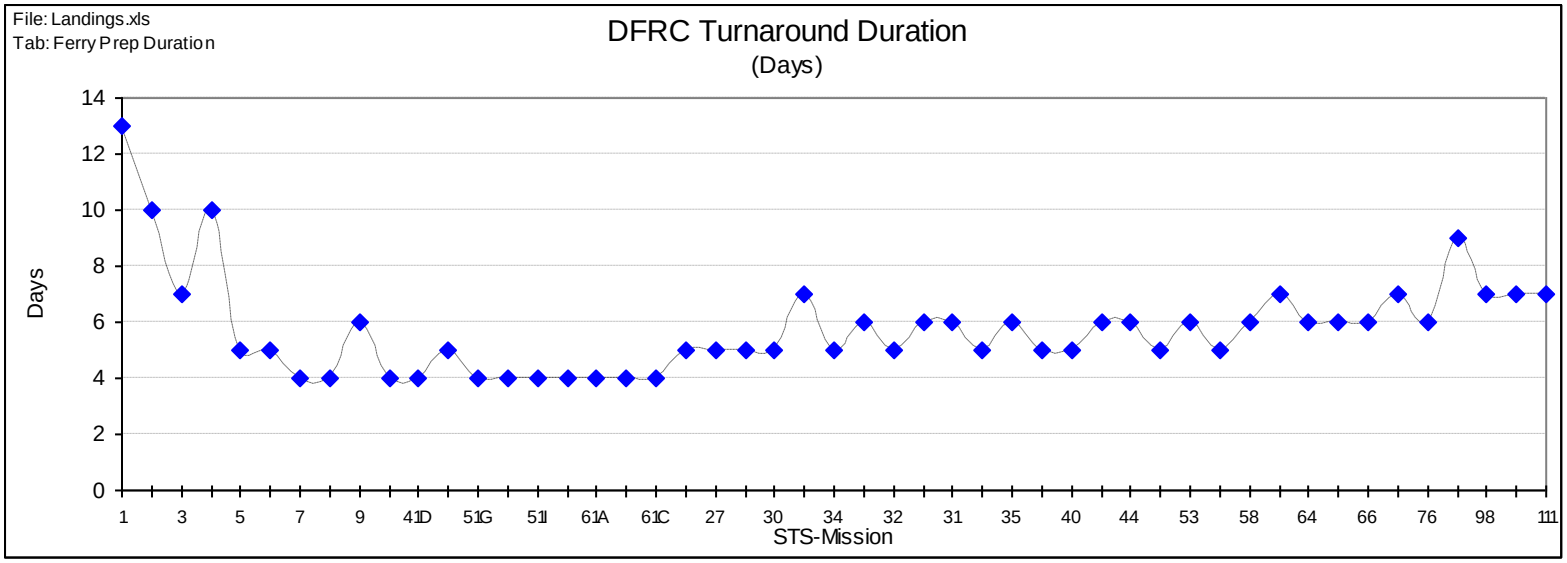
| Day 1 | | | Day 2 | | | Day 3 | | | Day 4 | | | KSC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WX Good at KSC | 0.64 | Land at KSC | | | | | | | | | | 0.64 |
| WX Not Good at KSC | 0.36 | | | | | | | | | | | |
| | 0.33 | Land at DFRC | | | | | | | | | | |
| | 0.67 | Stay On Orbit | | | | | | | | | | |
| Data Points 67 | | | WX Good at KSC | 0.47 | Land at KSC | | | | | | | 0.11 |
| | | | WX Not Good at KSC | 0.53 | | | | | | | | |
| | | | | 0.44 | Land at DFRC | | | | | | | |
| | | | | 0.56 | Stay On Orbit | | | | | | | |
| | | | Data Points 17 | | | WX Good at KSC | 0.33 | Land at KSC | | | | 0.02 |
| | | | | | | WX Not Good at KSC | 0.67 | | | | | |
| | | | | | | | 0.75 | Land at DFRC | | | | |
| | | | | | | | 0.25 | Stay On Orbit | | | | |
| | | | | | | Data Points 6 | | | WX Good at KSC | 1.00 | Land at KSC | 0.01 |
| | | | | | | | | | WX Not Good at KSC | 0.00 | | |
| | | | | | | | | | Data Points 1 | | | 0.79 |

Above table reflects Arena model representation.

# DFRC Contingency

- Current manifest ground rules show 6 days of Dryden Reserve.
  - This actually protects for a vehicle returning from Dryden and beginning the OPF flow on day 8 (relative to where it would be given a KSC landing).
    - Less 1 day for OPF flow work accomplished at DFRC (PRSD offload)
    - Less 1 day landing at DFRC vs KSC (counting procedure)
- Threats correlated with DFRC landings
  - Landing Delay in hope that KSC weather will improve.
  - Dryden Turnaround delays.
  - Delays during Ferry.
- Frequency of missions diverted to DFRC is approximately 21 percent.

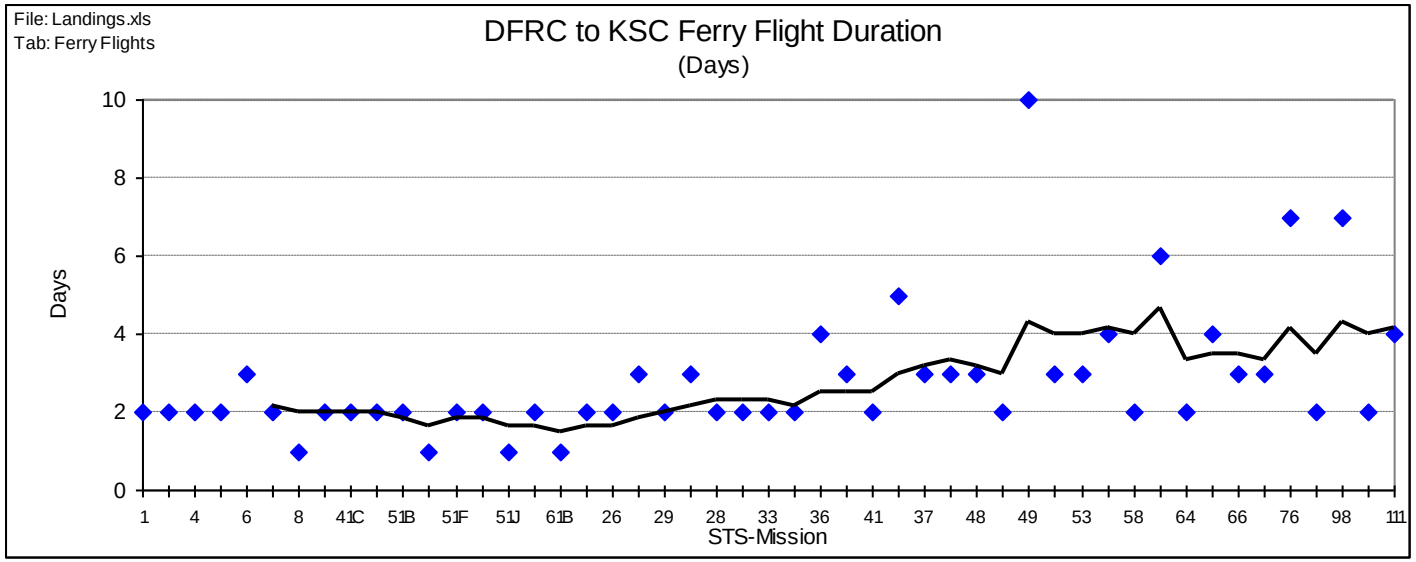
# DFRC Ferry Prep Duration




Ferry Prep Duration has been increasing.

- From 4 days at time of Challenger to 5 days in the early Return-To-Flight Era. This was the result of the addition of safety enhancements (e.g. Ball Valve Cavity Drain).
- Grew to 6 days due to scheduling of SCAPE activities and reduction of turnaround team.
- Grew to 7 days due to reduction of turnaround team on station at landing.
- Note that PRACA and weather conditions can result in 1-2 added work days.

# Ferry Flight Duration



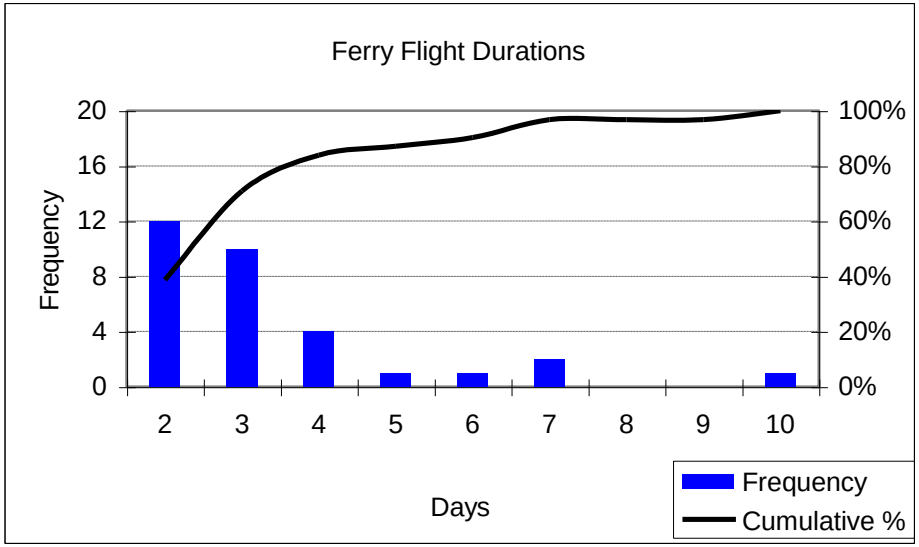

Ferry Flight Duration has been increasing.

The solid line shows a 6-flight moving average. Over the past several years the average time to ferry from DFRC to KSC has been 4 days. Planned ferry duration is typically 2 days.

During the late spring and early summer one day ferry flights are theoretically possible. However, none have been achieved in the Return-To-Flight era.

# Ferry Flight Duration

| Days | Frequency | Cumulative % |
|---|---|---|
| 2 | 12 | 39% |
| 3 | 10 | 71% |
| 4 | 4 | 84% |
| 5 | 1 | 87% |
| 6 | 1 | 90% |
| 7 | 2 | 97% |
| 8 | 0 | 97% |
| 9 | 0 | 97% |
| 10 | 1 | 100% |




Arena Representation:

DISC(.39, 2, .71, 3, .84, 4, .87, 5, .90, 6, .97, 7, 1.0,10)